

time-constant-to-discharge is 0.8 to 1.6  $\mu$ s. To charge the antenna **236** to a certain charge,  $Q$ , for a capacitance based on a dielectric constant for “free space” of  $\epsilon_0$ , i.e.,  $C_{\epsilon_0}$ , a voltage of  $V = Q/C_{\epsilon_0}$  is required. For the case of a capacitance, i.e.,  $C_{\epsilon_0,\epsilon}$ , which includes a detectable hand in “free space,” the voltage required to store charge  $Q$  is  $Q/C_{\epsilon_0,\epsilon}$ . However,  $C_{\epsilon_0,\epsilon}$  is about twice  $C_{\epsilon_0}$ , so that the voltage peak for the detected hand is about half of the no-hand-present case.

**[0100]** The diode **XD1 258** allows positive forward conduction but cuts off the negative backward conduction of a varying signal pulse. The forward current, or positive peak of the current, tends to charge the capacitor **XC5 260**. The diode **XD1 258**, the resistor **XR8 262**, the capacitor **XC5 260** and the bleed resistor **XR10 264** comprise a peak detector network. **XD1 258** and **XC5 260** capture the positive peak of the exponential waveform. **XR8 262** prevents oscillation of **XU1A 242**. **XR8 262** limits the charging time constant to 5 ms, where **XR8 262** is 4.99 k $\Omega$  and **XC5 260** is 0.1  $\mu$ F. This has an averaging effect on the peak detection and prevents noise spikes from pumping up the detector. The resistor **XR10 264** discharges the detector at a half-second time constant.

**[0103]** When the hand is detected, the stored charge on **XC8 260** is such that the voltage is sufficient to raise the input to the non-inverting terminal **266** of operational amplifier **XU1B 268** above  $\frac{1}{2}XV_{DD}$ , so as to drive that operational amplifier output to a usable linear voltage range.

**[0100]** The combination of the resistor **XR1 270** (e.g., 499 k $\Omega$ ) and the capacitor **XC1 272** (e.g., 0.1  $\mu$ F) comprise a low pass filter with a corner frequency of  $1/XR1 \bullet XC1$  (e.g., 20Hz), which corresponds to a time constant of  $XR1 \bullet XC1$  (e.g., 50 ms). This filter is for rejection of large 50Hz or 60Hz noise. These “high” frequencies are effectively shorted to ground. It is particularly helpful when the towel dispenser proximity detector is powered from an AC-coupled supply. The ubiquitousness of the AC power frequency, however, makes this protection desirable, regardless.

**[0105]** The signal is next amplified by an operational amplifier **XU1B 268**, which has a gain of 22. The resistor **XR5 277** serves as a feedback resistor to the negative (inverting) input terminal **279** of the operational amplifier **268**. There is a  $\frac{1}{2}XV_{DD}$  offset provided by the voltage divider network of **XR3 274** and **XR11 276**. The output rests against the negative rail until a peak exceeds  $\frac{1}{2}XV_{DD}$ . The charge

time adjustment **XVR1** becomes a very simple and sensitive way to adjust to this threshold. A setting of 3 V between test points **XTP1 278** and **XTP2 280** is recommended. This adjustment is made with all external capacitive loads (i.e., plastic and metal components) in place.

**[0106]** The output comparator **282** (Figure 10D) is connected to the signal processing from the operational amplifier **268** (Figure 10C) by the auto-compensate capacitor **XC3 284** (Figure 10D). This makes the circuit insensitive to DC levels of signal, but sensitive to transients, e.g., a waving hand. As long as the charge-time adjustment function remains in a linear range, the sensitivity to a moving hand will be stable.

**[0107]** The capacitor **XC4 286** allows the reference level (REF) **288** to track with approximately 50Hz or 60Hz noise on the SIGNAL **290** and not cause erroneous output pulses, since the AC noise will also track on the REF **288** (non-inverting) input to the comparator **282**.

**[0108]** The output stage of the proximity detector is implemented as a variable threshold comparator, **XU2B 282**. The signal is set up with an offset voltage, where the resistors **XR7 292** and **XR12 294** are equal and divide the  $V_{DD}$  voltage into two  $\frac{1}{2} V_{DD}$  segments. Three sensitivity settings are provided by **SW1 296**, high, medium, and low. These settings include where the reference voltage is the voltage drop across **XR6 298** (499 k $\Omega$ ) with the remainder of the voltage divider equal to **XR19 300** (453 k $\Omega$ ) plus **XR16 302** (20 k $\Omega$ ) plus **XR14 304** (10 k $\Omega$ ). This is the high setting, since the base reference voltage ( $V_{DD} \cdot 499 / [499 + 483]$ ) is greater than, but almost equal to the base signal value ( $V_{DD} \cdot 499 / [499 + 499]$ ). The signal must overcome, i. e., become smaller than the reference voltage (since the input is an inverting input) than the reference voltage, in order to swing the output **306** of the comparator **XU2B 282** high and activate, say, a motor-control latch (not shown in Figure 10D). The medium sensitivity setting, in Figure 10E, of switch **XSW1 296** (bypassing **XR14, 304** 10  $\Omega$ k, by way of switch **XSW1 296**) widens the difference between the signal and reference levels. The low sensitivity setting (bypassing **XR14 304**, 10  $\Omega$ k, and **XR16 302**, 20  $\Omega$ k, by way of switch **XSW1 296**), widens that difference between the signal and reference levels even more. Consequently, a larger difference between the signal and the reference voltage must be overcome to activate

the motor by way of the comparator XU2B 282 and the motor-control latch (not shown in Figure 10D).

[0109] The entire sensor circuit runs continuously on approximately 300  $\mu$ A at a supply voltage (XV<sub>DD</sub> 234) of 5 V.

[0110] Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims. Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the present invention, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present invention. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.